Function Generator Based on Circuit Simulation Method

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Abstract. The function generator has a wide range of applications, mainly used in various production testing and scientific and technological fields such as chemical industry, communication engineering, industrial control, military, aerospace and so on. The function calculator based on the circuit simulation method can be quickly adjusted according to the output frequency, amplitude, and phase under the premise of ensuring accuracy. This article uses Falstad for circuit simulation and TinkerCad for circuit modeling. From the circuit scheme selection, analysis, optimization and other links, all use electronic simulation, without using any physical electronic components. At the same time, the theoretical equation and the simulated function curve are compared. Through comparison, it is found that the overall trend of the simulated curve is similar to the theoretical value, but the maximum amplitude appears later and smaller than the theoretical value.

Keywords: Function Generator; Integrated Operational Amplifier; Circuit Simulation.

1. Introduction

A function generator is an electronic test device used to generate various waveform function signals, such as sine wave, cosine wave, square wave, staircase wave, sawtooth wave, white noise, pulse, etc [1]. The function generator has high precision and a high-frequency span, which can reach frequencies as low as a few μHz and as high as tens of MHz. Because of this, it has a wide range of applications and is mainly used in various production testing and scientific and technological fields, such as chemical engineering, communication engineering, industrial control, military, and aerospace [2-3]. Therefore, it is necessary to study the function generator.

Zhang and Du [4] found that a function generator can relate the desired functional relationship between motor output and motor input. But this kinematics is time-dependent due to the reliability in the time interval defining the functional relationship. Yao et al. [5] found the main advantage of the function calculator based on the circuit simulation method is that it can be adjusted quickly according to the output frequency, amplitude, and phase under the premise of ensuring accuracy. At the same time, using software to simulate circuits instead of physical electronic components can greatly reduce the influence of electronic components' aging, thermal drift and human factors on simulation experiments. Kokolanski and Simic [6] believe that any type of waveform for which the mathematical equation is known can be generated using the software. This enables simulations that would be nearly impossible to do with normal function generators. Output waveforms and algebraic formulas for any signal can be obtained using a computer simulation-based function generator. Therefore, this paper conducts detailed research on the function generator based on the circuit simulation method and provides a certain direction for its future development.

In this paper, Falstad will be used to simulate the circuit and use TinkerCad to model the circuit. The circuit scheme selection, analysis, optimization, and other links are all carried out utilizing electronic simulation without using any physical electronic components. This method not only saves experimental expenses, simplifies the design process, but also greatly shortens the design cycle while ensuring the accuracy of experimental design.

2. Methods

2.1. The falstad circuit model

The function generator in this project is mainly composed of summing amplifier, integrator, and inverse proportional operator. The most common inverting summing amplifier is shown in Figure 1.

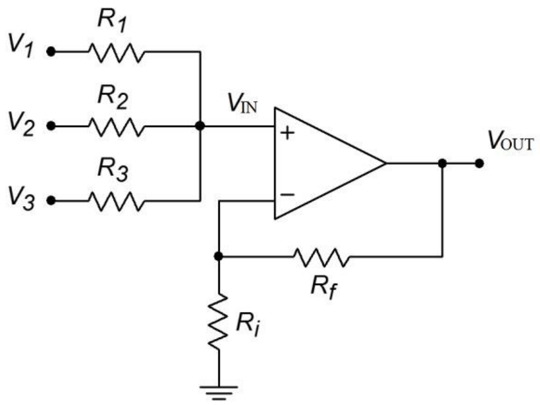

Fig 1. The summing amplifier circuit [5].

Then the current and voltage of this circuit are

$$I_F = I_1 + I_2 + I_3 = -\frac{V_1}{R_{in}} + \frac{V_2}{R_{in}} + \frac{V_3}{R_{in}} \tag{1}$$

$$V_{out} = -\frac{R_f}{R_{in}} \times V_{in} \tag{2}$$

$$-V_{out} = \left[\frac{R_f}{R_{in}} V_1 + \frac{R_f}{R_{in}} V_2 + \frac{R_f}{R_{in}} V_2\right] \tag{3}$$

An integrated circuit is the basic unit of an analog computer, and it is a circuit that achieves the purpose of simulating differential equations. The analog circuit of the integrating amplifier is shown in Figure 2. It can be used in waveform transformation, elimination of offset voltage in amplifier circuits and integral compensation in feedback control. At the same time, an integrated circuit is also an important unit commonly used in control and measurement systems, and its charge and discharge process can be used to achieve delay, timing, and generation of various waveforms.

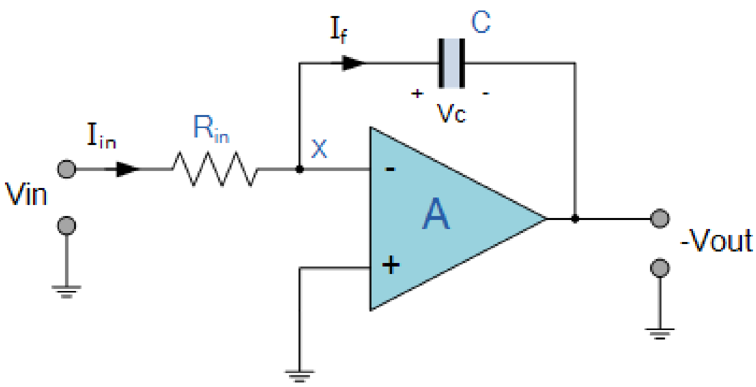

Fig 2. The integrator amplifier [6].

There are many basic circuit element units in the circuit configuration of the operational amplifier, among which the most basic configuration is the non inverting operational amplifier. When it works, its working principle is simple. It uses a negative feedback connection to produce an output with a phase difference of 180 ° from the input phase.

The output voltage of the inverting op-amp is

$$i = \frac{V_{in} - V_{out}}{R_1 + R_2} \tag{4}$$

$$V_{out} = -\frac{R_2}{R_1} \times V_{in} \tag{5}$$

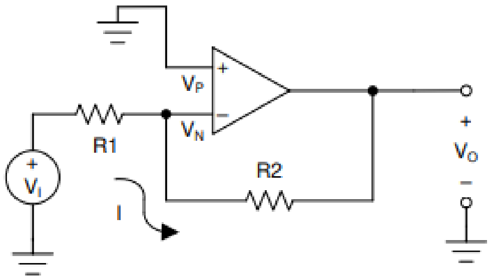

Fig 3. The inverting amplifier [9].

The circuit that needs to be simulated is shown in Figure 4. Through the above analysis, it can be concluded that the Falstad circuit is composed of a summing amplifier, two integrators and an inverting amplifier.

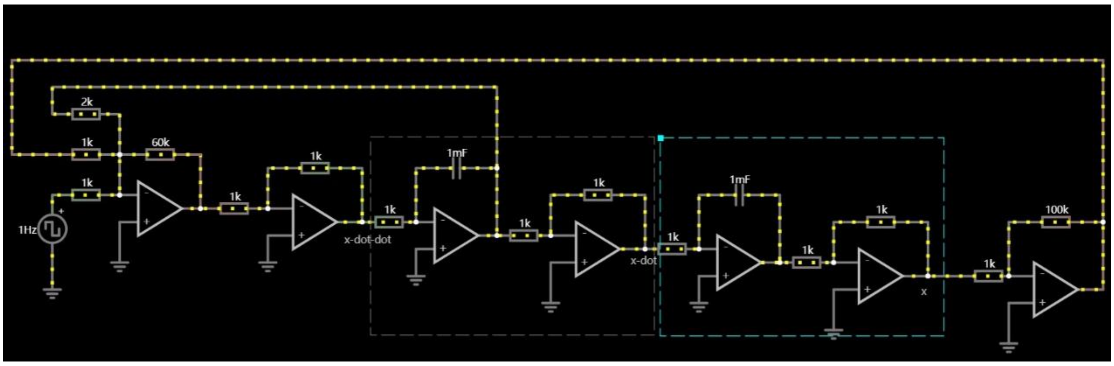

Fig 4. The falstad circuit.

2.2. Circuit by TinkerCad

TinkerCad is an online software toolset for creating 3D models. The circuit simulation module allows the construction and programming of circuits using fundamental physical components [10]. According to mentioned above, Figure 5 shows the circuit simulation by TinkerCad. The circuit uses a square wave function to simulate at a frequency of 1 Hz and an amplitude of 500 mV.

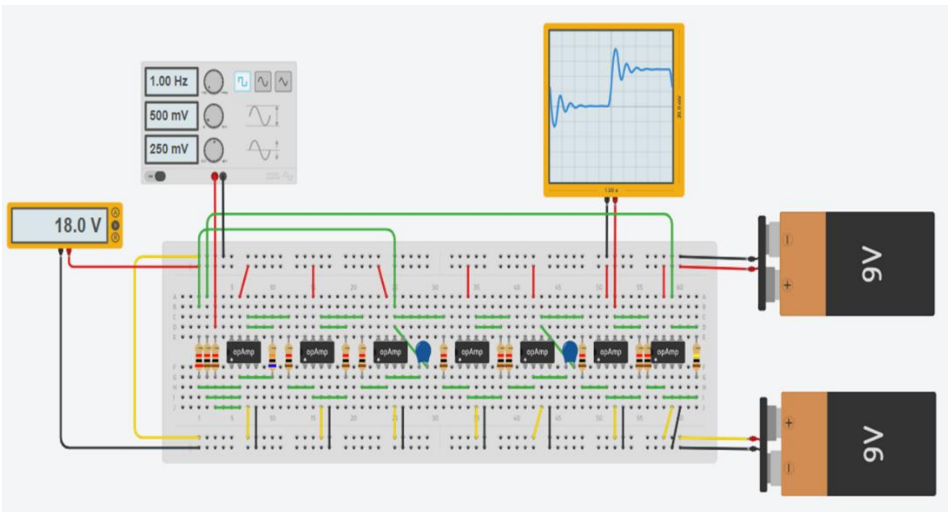

Fig 5. Circuit by TinkerCad.

3. Result and discussion

3.1. Theory result

It can be seen from Figure 4 that the simulated circuit is composed of an adder, two integrators, and an inverting amplifier. From this, it can be concluded that the calculator equation expressed by the circuit is

$$-\ddot{x} = -60k \times \left(-\frac{\dot{x}}{2k} + \frac{-100x}{1k} + \frac{f(t)}{1k}\right) = 30\dot{x} + 6000x - 60f(t) \tag{6}$$

$$\ddot{x} + 30\dot{x} + 6000x = 60f(t) \tag{7}$$

When

$$x(0) = 0mV \tag{8}$$

$$\dot{x}(0) = 0mV/s \tag{9}$$

Solving the ODE when t $\in$ [0, 0.5]. Then the Equation (7) will be transferred to

$$x = \frac{\frac{-\sqrt{231}\sin(5\sqrt{231}t)}{15400} - \frac{\cos(5\sqrt{231}t)}{200}}{e^{15t}} + \frac{1}{200} \tag{10}$$

According to the Equation (10), the function curve is shown in Figure 6.

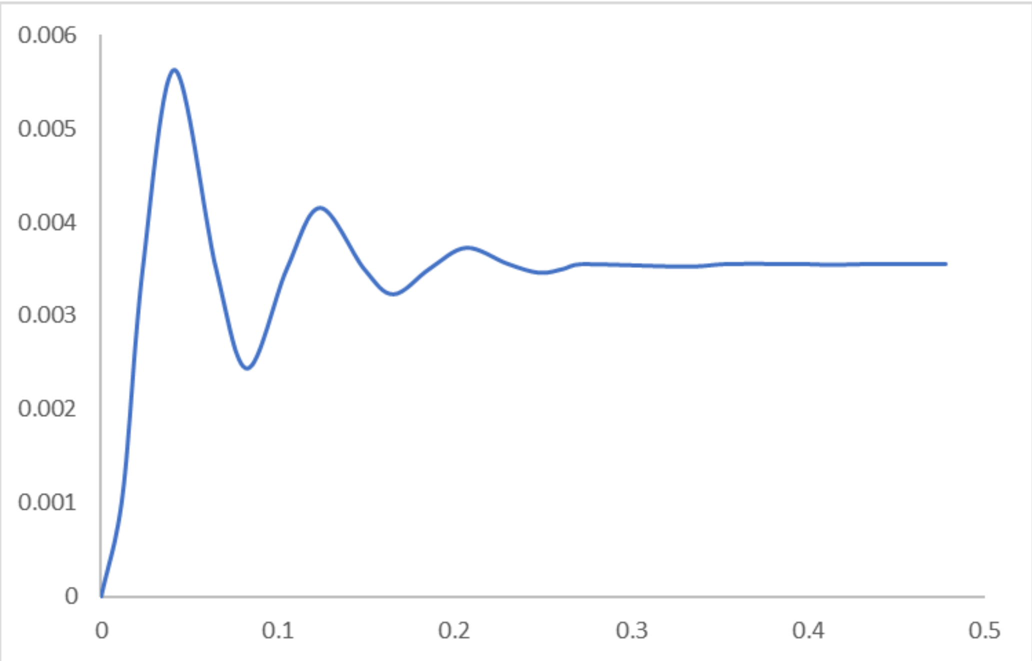

Fig 6. Function curve of the Equation (10).

3.2. Comparison between theory and simulation

Figure 7 is the function curve simulated by Falstad. Compare it with Figure 6, in terms of the trend of the overall curve, the simulated results are somewhat similar to the theoretical results. However, its peak value is slightly different from the theoretical value, that is, the maximum amplitude appears relatively later and smaller than in the theoretical value. This discrepancy may have something to do with the Elmore delay. This provides a certain basis for future work directions.

Fig 7. The simulated curve by Falstad.

4. Conclusion

In this paper, the circuit is simulated by Falstad, and the circuit is modeled by TinkerCad. The circuit scheme selection, analysis, optimization and other links are all carried out by means of electronic simulation without using any physical electronic components. At the same time, the theoretical equation and the simulated function curve are compared. Through comparison, it is found that the overall trend of the simulated curve is similar to the theoretical value, but the maximum amplitude appears later and smaller than the theoretical value.

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